WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

"IMPROVING PRODUCTIVITY OF SERVICE BUSINESSES WITH A NEW EFFICIENCY EVALUATION TECHNIQUE"

by

H. David Sherman
Sloan School of Management
Massachusetts Insitute of Technology

Revised October 1983

SSM Working Paper # 1498-83

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

"IMPROVING PRODUCTIVITY OF SERVICE BUSINESSES WITH A NEW EFFICIENCY EVALUATION TECHNIQUE"

by

H. David Sherman
Sloan School of Management
Massachusetts Insitute of Technology

Revised October 1983

SSM Working Paper #1498-83

How can a manager evaluate the productivity of a bank branch, a hospital, or other service organization? A bank branch may have outstanding profit performance based on a measure of the revenues earned on funds less the costs of funds generated, and less the operating costs. This measure does not, however, indicate whether the branch is using its resources efficiently or whether it could reduce its operating costs and further increase profitability. Similarly, if one hospital provides patient care at a cost of $300 per day and another provides patient care at $350 per day, can a manager draw any conclusions about their relative productivity without further considering the mix and nature of patient care provided? Measuring the productivity of these and other service businesses requires techniques that are more sensitive than accounting and ratio type measures and which can explicitly consider the mix of service outputs produced. This article explains how to apply a recently developed method for measuring and improving the efficiency of service businesses. The technique, referred to as Date Envelopment Analysis, has thus far been applied to banks, hospitals, computer manufacturer field service organizations, and educational institutions, as well as other service organizations.

INTRODUCTION

The service sector of the U.S. economy has been estimated to account for over 60% of Gross National Product and employment. Add to this the service components of manufacturing firms and it is clear that service sector productivity is a substantive issue as suggested in the following examples.

- Over 20% of computer manufacturer revenues are generated from customer service activities. These companies need to monitor and manage the service aspect of their business to help achieve their growth and profitability goals.

- Hospital cost increases are a serious and continuing concern. Their management are increasingly accountable for assuring efficient delivery of health care services.

- Public sector organizations face continued taxpayer pressures to maintain service at or above current levels but at a lower cost.

Although the need for managerial methods to enhance productivity in the service industry is apparent, techniques to accomplish these improvements have not been developed as they have for the manufacturing sector.

Service business efficiency is often more difficult to evaluate than manufacturing business efficiency because the efficient amount of resources required to produce service outputs is difficult to determine. The standard or efficient cost of a manufactured product can generally be determined with some precision. This manufacturing standard can be used to identify operating inefficiencies by analyzing differences between actual cost and standard costs through classical cost accounting variance analyses. (1) Service organizations have not generally developed standard cost estimates of outputs. One reason for this is that the specific resources required to provide a specific service output are difficult to identify. (This, of course, is also true of manufacturing organizations that produce highly customized products.) Another reason may be that those being evaluated against a standard cost would not accept or be able to agree on a standard because of the professional judgement involved in providing each type of service. For example, the professional might convincingly argue that no two audits, heart operations, or customer service calls are alike, so that no standard or efficient input level can be identified as a basis for evaluating the efficiency of producing such services.

Another approach to evaluate service productivity is to develop a series of output to input ratios such as full-time equivalents per service unit,

dollars per transaction, etc. The idea is that units with higher costs per transaction would be potentially less efficient than those with lower costs. For example, a measure of bank branch operating efficiency that might be used is the ratio of cost per teller transaction. The branch with the higher cost per teller transaction may be less efficient. Alternatively, this higher cost per transaction may be due to a more complex mix of transactions. That is, a branch which primarily opens new accounts and sells certificates of deposit would require more resources per transaction than another branch that primarily processes less complex transactions such as deposits and check cashing. In short, the problem with these ratio measures is that the mix of outputs is not explicitly considered.

Profitability, return on investment, and other financial ratios are highly relevant as performance measures of many service businesses, but they are not sufficient to evaluate operating efficiency. For example, a bank branch may be profitable when profit reflects the interest and the revenues earned on funds generated by a branch less the cost of these funds and less the costs of operating the branch. This profit measure does not, however, indicate whether the resources used to provide customer services are being managed efficiently. The branch that processes a high proportion of cash withdrawals and other non-fund-generating services may have higher operating costs and lower profitability than one which processes a lower proportion of nonfund generating transactions. Nevertheless, the less profitable branch may be more efficient using its personnel and other inputs than the more profitable branch. In this instance, the more profitable branch may be able to provide its same service level with fewer inputs which would result in lower operating costs and yet greater profitability. For non-profit organizations, profit maximization is generally a secondary consideration

and the need for other types of performance measures is even more acute than in the for-profit service businesses.

There are also differences within the service sector organizations that need to be considered in adopting performance evaluation techniques. Professional service organizations, such health care, management consulting, and accounting firms experience greater difficulty defining efficient input/output relationships than other types of service organizations where labor inputs are highly controlled and standardized, such as fast food restaurants. This is most evident when one examines a text on operations management in service businesses (see for example [2]). The management techniques that are described in such a text tend to be extremely useful in managing a McDonald's restaurant but are of only marginal value in running a health care clinic. In contrast, texts discussing management of nonprofit service organizations such as [3] reflect keen awareness of the difficulty of measuring outputs and determining the efficient level of inputs required; however, solutions to these problems are not provided in any detail.

Recently, a new technique was developed which has the ability to compare the efficiency of similar service organizations by explicitly considering their use of multiple inputs (resources) to produce multiple outputs (services). The technique, referred to as Data Envelopment Analysis (DEA), circumvents the need to develop standard costs for each service provided. It provides a measure of efficiency that is explicitly sensitive to the output mix and is consequently more comprehensive and reliable than use of a set of operating ratios and profit measures. Data Envelopment Analysis compares a set of service organizations and identifies units that are relatively inefficient, the magnitude of the inefficiency, and alternative paths to reduce the identified inefficiencies. Management can use DEA to identify the inefficient units and the magnitude of the inefficiency. In

addition, DEA can help assess plans to remedy and reduce these inefficiencies. This can lead to (1) a reduction in the cost of operations or (2) an increase in the services provided without an increase in the level of resources utilized by the inefficient units.

DEA is a linear programming technique originally developed by Charnes, Cooper, and Rhodes ([4], [5], and [6]) to evaluate nonprofit and public sector organizations and has subsequently been found to be a valuable tool in application to a variety of corporate service type organizations. DEA has been applied to hospitals [7], primary and secondary educational institutions [6], [8], court systems [9], armed forces recruiting offices, bank branches [10], and customer service offices of a computer manufacturer.

The following section briefly describes and illustrates how DEA works. The appendix provides details about how DEA can be applied using any standard linear programming package. The subsequent section describes how this has been applied to hospitals and bank branches. The final section discusses the strengths and limitations of DEA and how management can use DEA to evaluate and improve operating efficiency of service organizations.

Data Envelopment Analysis - How it Works and How to Interpret the Results

Use of DEA to evaluate efficiency will be illustrated with a simplified bank branch example where there is only one type of transaction processed and two types of resources used to processes these transactions - bank tellers and supplies. This example was selected because it lends itself to an easily visualized graphic description. In addition, this example is simple enough to be analyzed without DEA, so that the results can be compared to an independent analysis of efficiency. Note that DEA is most valuable in complex situations where (1) there are multiple outputs and

inputs that cannot readily analyzed with other techniques like ratios, and (2) where the number of service organization units being evaluated are so numerous that management cannot afford to evaluate each unit in depth. For example, an actual bank application included 18 different transaction types as output measures and 14 branches were to be evaluated. DEA was used to help direct management's efforts to improve efficiency of units that were first identified as inefficient with this technique.

Assume that there are five bank branches (B1, B2, B3, B4, and B5) that each process 1,000 transactions such as deposits by jointly using two inputs, tellers measured in labor hours (H) and supplies measured in dollars (S) during one common time period (week, month, year, etc.). The amount of inputs are summarized in table 1.

Table 1

	SERVICE OUTPUTS	INPUTS USED	
SERVICE UNIT	TRANSACTIONS PROCESSED (T)	TELLER HOURS (H)	SUPPLY DOLLARS (S)
B1	1,000	20	300
B2	1,000	30	200
B3	1,000	40	100
B4	1,000	20	200
B5	1,000	10	400

The problem facing the manager is to identify which of these branches are inefficient and the magnitude of the inefficiency. This information could be used to locate the branches that require remedial management action, to reward the more efficient managers, and/or to determine the management techniques that are used in the more efficient branches so that they can be transferred to less efficient branches to improve their operating efficiency. While the manager can observe the number of transactions processed and the amount of resources (H and S) used, the manager does not

know the efficient output/input relationship. That is, the efficient amount of labor and supplies needed for each transaction is not readily determinable. Hence, the problem might be visualized as in Figure 1.

In this example, it can be observed that B1 and B2 are relatively inefficient. B1 produced the same output level as B4 but used 100 more supply dollars (S) than were used by B4. B2 also produced the same output level as B4 but achieved this through the use of 10 more Teller labor hours. With the information available in table 1, it is not possible to determine whether B3, B4 or B5 are more or less efficient. While information about relative prices might allow one to rank B3, B4 and B5, the finding that B1 and B2 are inefficient would not change. That is, B1 and B2 should be able to reduce inputs without reducing outputs regardless of the price of the inputs.

Data Envelopment Analysis compares each service unit with all the other service units and identifies those units that are operating inefficiently compared with other units' actual operating results. It accomplishes this by locating the best practice units, (units that are not less efficient than other units being evaluated) and measures the magnitude of inefficiency compared to the best practice units. The best practice units are relatively efficient and are identified by a DEA efficiency rating of E = 100%. The inefficient units are identified by an efficiency rating of less that 100% (E < 100%).

The DEA techniques and the data needed to apply DEA are described in Exhibit I. DEA is applied to the example in Table 1 in Exhibit I.

DEA first provides the type of information summarized in table 2.

Figure 1

Problem: Which are the inefficient branches and what is the magnitude of the inefficiency present?

BANK BRANCH OFFICE	OBSERVED INPUTS	PRODUCTION PROCESS UNKNOWN	OBSERVED OUTOUT IN UNITS
B1	20 units of H 300 units of S	?	1000 transaction
B2	30 units of H 200 units of S	?	1000 transaction
B3	40 units of H 100 units of S	?	1000 transaction
B4	20 units of H 200 units of S	?	1000 transaction
B5	10 units of H 400 units of S	?	1000 transaction

Table 2

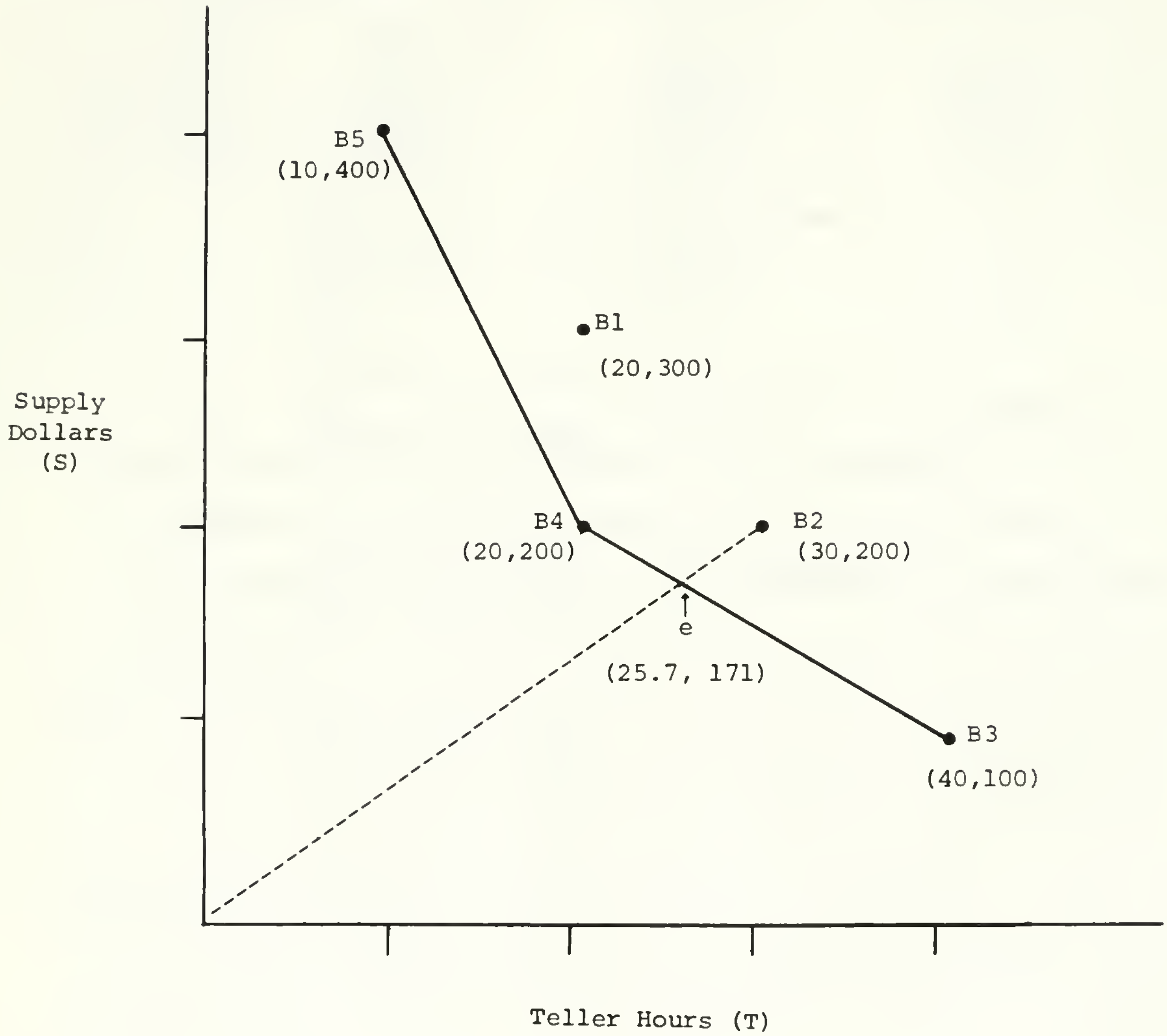
DEA RESULTS

SERVICE UNIT	EFFICIENCY RATING (E)	EFFICIENCY REFERENCE SET	
B1	85.7%	B4 (.2857)	B5 (.7143)
B2	85.7%	B3 (.7143)	B4 (.2857)
B3	100.0%	N/A	
B4	100.0%	N/A	
B5	100.0%	N/A	

Table 2 indicates that DEA identified the same inefficient branches that were identifiable through observation of the data. B1 and B2 have efficiency ratings below 100% which identifies them as inefficient. In addition, DEA further focuses the managers attention to a subgroup of the bank branches which are referred to as the efficiency reference set in Table 2. This efficiency reference set includes the group of service units against which each inefficient branch was most directly found to be inefficient. For example, B1 was found to have operating inefficiencies in direct comparison to B4 and B5. The value in parenthesis in Table 2 represents the relative weight assigned to each efficiency reference set member to calculate the efficiency rating (E). (This corresponds to the non-zero shadow prices of the constraints which is directly available from the DEA linear program output.) More specific information about the nature and magnitude of the inefficiency present are available from the DEA results as is illustrated in Figure 2 using B2 as an example.

Figure 2

All branches produce 1000 units of a single transaction type (T) using the following amounts of Teller Hours (H) Supply Dollars (S).



DEA has determined that the relatively efficient bank branches among the five are B5, B4, and B3. This can be represented in this simple case by the solid line in Figure 2 which locates the units that used the least amount of inputs to produce their output level. DEA indicates that B2 is inefficient compared to the line connecting B4 and B3; B2 is 85.7% efficient compared to B4 and B3. This means that one way for B2 to become efficient is to reduce its inputs to 85.7% of its current level which would move B2 onto this relatively efficient production segment at point e in Figure 2, which reflects use of 25.7 teller hours (.857 X 30) and use of 171 supply dollars (.857 X 200). DEA provides information to complete the calculation suggested in Figure 2. This is illustrated in Table 3.

Table 3 indicates that a mixture of operating techniques utilized by B3 and B4 would result in a composite hypothetical branch that processes the same amount of transactions (1,000) processed by B2 but also requires fewer inputs than were used by B2. Hence, by adopting a mixture of the actual technique used by B3 and B4, B2 should be able to reduce teller hours by 4.3 units and supply dollars by 29 units without reduction in its output level. A similar calculation can be completed for each inefficient unit located via a DEA analysis.

Management is also provided with alternative paths to improve efficiency of B2. One path suggested in Table 3 is for B2 to reduce H by 4.3 units and reduce S by 29 units. Other paths are ascertainable from the DEA output as follows: DEA calculates a relative value for each input and output (the v_1 and v_2 values that result in the efficiency rating as noted in Exhibit I). For branch B1, this value is 1.436 for teller hours (H) and 0.286 for supply dollars (S). This means that for each unit of reduced teller hours, the efficiency of B2 increases by 1.43%; and for each unit

Table 3

OUTPUT		OUTPUTS AND INPUTS OF B3		OUTPUTS AND INPUTS OF B4		COMPOSITE OF THE EFFICIENCY REFERENCE SET FOR SERVICE UNIT B2
Transaction Processed (T)	(.2857) x	1000	+ (.7143) x	1000	=	1000
INPUT						
Teller Hours (T)		40		20		27.5
Supply Dollars (S)		100		200		171

The composite for B2 can then be compared with the inefficient unit B2 as follows:

	COLUMN 1 COMPOSITE OUTPUTS AND INPUTS (FROM ABOVE)	COLUMN 2 BRANCH B2 ACTUAL OUTPUTS AND INPUTS	COLUMN 2 - COLUMN 1	
O_1	1000	1000	0	
I_1	25.7	30	4.3	Excess
I_2	171	200	29	Inputs Used by Branch B2

decrease in supply dollars, the efficiency of B2 will increase by 0.286%. For B2 to become relatively efficient, it must increase its efficiency rating by 14.3percentage points. Hence, B2 can become efficient by decreasing H by 10 hours (10 hours X 1.43% = 14.3%) or by decreasing S by 50 units (50 X 0.286% = 14.3%) or by some combination of these reductions in H and S. The choice of which path to follow would, of course, be based on management's evaluation with respect to cost, practicality, and feasibility under the particular organization's circumstances.

At this point it must be reemphasized that DEA results are most useful when there are multiple outputs and inputs and where the type of intuitive analysis that could be applied to verify the DEA results in the above example would not be possible. Nevertheless, the efficiency rating, the efficiency reference set, the analysis as performed in Table 3, and the ability to determine alternative paths that would make an inefficient unit efficient would all be readily available.

How Can A General Manager Understand All This Technical Material?

Business application of DEA to banks, hospitals, and customer service organizations suggests that the presentation along the lines of Table 3 is one of the most direct ways to summarize and explain what DEA has achieved and the implications to management. The interpretations of DEA results tend to proceed in the following order:

- The efficiency ratings are generated as in Table 2. Units that are efficient (E = 100%) are relatively and not strictly efficient. This means that there is no other unit that is clearly operating more efficiently than this unit but it is possible that all units including these relatively efficient units can be more efficiently operated. The efficient branches, B3, B4, and B5, therefore, represent the best practice but not necessarily the best possible management practice.

- Inefficient units are located with efficiency rating of E < 100%. These units, B1 and B2, are strictly inefficient compared to all the other units and are the ones where remedial action by management should be considered. In fact, the inefficiency identified with DEA will tend to understate rather than overstate the inefficiency present.

- The efficiency reference set indicates the relatively efficient units against which the inefficient units were most clearly determined to be inefficient. The presentation in Table 3 summarizes the magnitude of the inefficiencies located by comparing the inefficient unit with its efficiency reference set.

- The results in Table 3 might be summarized as follows:

  B2 has been found to be relatively less efficient than a composite of the actual output and input levels of B3 and B4. If a combination of operating techniques used in B3 and B4 were transferred to inefficient unit B2, B2 should be able to reduce the amount of H used by 4.3 units and reduce the amount of S used by 29 units while providing the same level of services. Other methods to improve efficiency are also identifiable via DEA, such as were described above, which should also be considered by management in designing a program to improve the efficiency of each inefficient unit identified by DEA.

Table 4

Comparison of Teaching Hospitals' Medical Surgical (MS) Area

Hospital (1)	DEA Efficiency Rating (2)	Efficiency Reference Set (ERS) (3)	Medical-Surgical Area Cost Per Patient Day (4)
A	100	-	$34
B	100	-	38
C	100	-	39*
D	88	A, C, E	32
E	100	-	27
F	100	-	29
G	93	E	36
	Average Cost		$34.29
	Standard Deviation		$ 4.27

Hospital Application

A set of teaching hospitals were compared and evaluated using DEA. The inputs were identified as bed days available, full-time equivalents of non-physician staff, and supply dollars. Outputs included measures of number of interns, residents and nurses trained and the number of bed days of care administered for each patient type.

The DEA results located a set of inefficient hopsitals not otherwise identifiable using ratio analysis techniques (e.g., cost per day, cost per patient), the method used by the local regulatory agency which needs this type of data to affect hospital reimbursement rates. The DEA results were found to be meaningful and accurate by a panel of hospital experts familiar with these hospitals. Moreover, management of one inefficient hospital acknowledged the inefficiencies identified with DEA particularly with respect to their use of excessive personnel and bed days.

The DEA results focusing on the medical/surgical areas of a group of these hospitals are in table 4 along with the ratios of cost per patient day of care. The cost per patient day is a typical example of ratio which might be used to locate high and low cost hospitals. Note that there is no objective means of establishing a cutoff cost level which separates the more and less efficient hospitals. The local regulatory agency defined potentially inefficient hospitals as those which have costs over one standard deviation above the mean. This "rule of thumb" identifies only hospital C as inefficient. In addition, there is no way to determine if this represents use of excess inputs or payment of higher prices for their inputs. In addition, hospital C may have higher costs primarily because it

treats more complex patient illness or provides greater amounts of teaching services. These are typical problems associated with financial and operating ratios.

DEA identified two hospitals, D and G, as inefficient in their use of inputs to produce the actual mix of patient care and teaching services provided. Note that these hospitals would have gone unnoticed using ratios. Unlike the ratios, the use of DEA allowed for explicit consideration of case mix and teaching outputs. DEA identified the use of excess amounts of inputs in specific hospitals without the need for an arbitrary or subjective decision rule as to which units are inefficient. Correcting these inefficiencies would result in yet lower costs for hospitals D and G.

Management of hospital D studied the detailed DEA results and agreed that they had an excessive number of beds and personnel compared with the other hospitals. They planned to reduce the number of beds by 19, freeing up space for other uses. They also determined that personnel levels were excessive by 5.4 full-time equivalents but chose not to make any reductions here because their policy was to maintain high personnel levels to provide more personalized care. The planned reduction in the number of beds was reevaluated using DEA. This indicated that this hospital would still be rated as inefficient but with a higher rating of 96% compared with the original level of 88%. If they also reduced personnel by the 5.4 units they identified, their DEA efficiency rating would have increased to 100.

Hence, DEA provided a basis for improving productivity by reducing the number of beds and it indicated reduction in personnel were possible without affecting output levels which could further reduce costs. In this case, DEA also helped to clarify the cost of the intended inefficiency or slack and challenges management to justify this cost. Thus, DEA provided insights

about inefficiencies not available from ratio analysis. Nevertheless, the questions raised about the cost per patient day and other similar ratios are also relevant. Hence, DEA is a complement to, rather than a substitute for, other types of analysis.

Savings Bank Application

Branches of a savings bank were compared using DEA to assess their operating efficiency. The bank's head office management developed a branch profit measure which was considered to be useful in evaluating a number of dimensions of branch performance. This profit measure did not, however, provide information about branch resource utilization because the transaction mix was not considered and the profit was mostly a measure of earnings from funds generated by each branch. Hence, the potential benefits of applying DEA were of interest. The process began by identifying relevant outputs and inputs of a branch. Inputs included personnel full-time equivalents and supply costs. Outputs were identified as the number of each of seventeen transaction types, including for example, opening new accounts, withdrawals, deposits and issuing savings bonds.

DEA was first used to identify inefficient branches and the magnitude of input reductions that were possible. This result was not apparent from other evaluation techniques used in the bank including profitability measures and operating ratios such as cost per transaction and number of transactions per FTE. DEA indicated that six of the 14 branches were inefficient. Most of the branches identified as inefficient were consistent with head office management expectations based on their view of quality of the managers in these branches. However, one branch identified as inefficient was a complete surprise to management. This information was particularly useful because it quantified the operating inefficiencies which

were only vaguely apparent to management based on their intuition about the branch managers. Moreover, this insight was obtained without the need to involve branch managers in any part of the process, since the output and input data were already available at the head office.

DEA first alerted management to the branches that were inefficient and the magnitude of the inefficiency. This allowed management to assess the potential benefits of taking remedial action. Beyond this, DEA specified the efficient branches against which the inefficient branches should be compared to understand and locate the source of the inefficiencies. By comparing the operating techniques in the narrowed set of efficient and inefficient branches, management could identify the techniques which require improvement and the techniques which should be transferred from the more efficient branches to the less efficient branches to improve the latter's performance.

Use of DEA alerted management to cost saving opportunities that were not apparent with other techniques and it helped management to allocate their time and remedial efforts to areas where operating weaknesses were now known to exist. Based on favorable reaction to this effort, bank management further proposed to use DEA to compare their branches with those of another bank they were acquiring to determine if there were opportunities for improving operations through the transfer of good branch management techniques from the original to the newly acquired branches or *vice versa*.

The above examples illustrate the use of DEA to compare organizations that jointly produce a set of similar service outputs with a set of inputs. This can readily be applied across organizations in the non-profit sector where data are publicly available as in the teaching hospital example.

Corporate applications of DEA will tend to emphasize cases where management wants to evaluate and improve efficiency of a set of offices providing similar services as in the bank example. It would also be possible to compare independent competing firms using DEA, but this type of data would generally be difficult to obtain due to the condifentiality of detailed operating data. Consequently, the corporate applications will generally be limited to comparison of multiple service offices such as bank branches, customer services officers, multi-office CPA firms, and insurance claims offices.

How Would Management Apply DEA

Step 1: Management would identify the units for which a DEA efficiency evaluation would be of interest. This would generally be a set of units that provide similar services for which management wants to evaluate performance and improve operating efficiency.

Step 2: The relevant outputs and inputs of the units to be evaluated would be identified by management and measured for a representative period of time (year, quarter, month). The relevant outputs are those services and other activities that the unit is responsible for to achieve its business purpose. The inputs are those resources that are required to produce the designated outputs. Field applications of DEA have indicated that this process of output and input indentification in itself is often useful to managers, as the outputs and inputs are frequently not explicitly identified or understood. In addition, some of the relevant outputs and inputs may not have been measured or captured in the management information system of the firm. The absence of data on relevant outputs and inputs has tended to raise questions about the adequacy of the information system, since this type of input-output data are needed to assess operating performance

regardless of the techniques that may be used. Generally, the outputs used should be related to the inputs selected in that an efficient unit should be expected to respond over time to an increase or decrease in outputs with a corresponding increase or decrease in the various inputs.

If all the relevant outputs and inputs are not included in the DEA analysis, the DEA results will have to be reviewed for any bias that might result. For example, the DEA application to hospitals excluded a measure of the quality of services. Such use of DEA requires that the results be reconsidered to determine if the inefficient hospitals' quality of care exceeds the efficient hospitals' quality of care by a large enough margin to compensate for the DEA calculated inefficiency. The hospital application that addressed this issue found that quality of care was not a compensating factor. Other applications of DEA may, however, require some qualification if certain relevant input or output measures are excluded.

Step 3: DEA would be applied to the output and input data and the results would be analyzed to help management locate and remedy operating inefficiencies. Generally, management will not have seen results similar to DEA and these results will tend to provide insights not available from other widely used analytical techniques such as ratio analysis. Management might begin by considering whether the location and magnitude of inefficiencies are consistent with their prior view of the operations of the service units being evaluated. This may raise questions about the completeness and representativeness of the output and input data.

The inefficient units would then be further studied and compared with their efficiency reference set units to evaluate the cause and controllability of the identified inefficiencies. In some cases, the inefficiencies present may represent intended slack built into a unit or special circumstances which do not permit improvements in operating

efficiency. In this circumstance, DEA helps to understand the cost of this inefficiency and no further managerial actions may be warranted. When the inefficiencies are found to be associated with the systems and managerial techniques used in these units, remedial action to improve efficiency would be implemented.

Insights from DEA direct management's attention to aspects of operations which are highly likely to benefit from remedial action. In contrast to other techniques, DEA evaluates units by explicitly and simultaneously considering the multiple inputs used to produce multiple outputs and without the need to know the efficient input/output relationships. Although DEA does not actually specify the remedial action needed, it narrows the focus of management's investigation to the inefficient units and their efficiency reference set. Through this process, DEA helps allocate management support to areas where weaknesses are known to exist and helps management identify ways in which management techniques can and should be improved.

Dynamic Analysis with DEA

In addition to the static one year or period analysis such as was completed for the bank branches and hospitals, DEA can monitor and thereby help control the level of operating efficiency over time. DEA can be run with multiple period information (quarters, years, etc.) for individual ogranization units or for each of a set of units being compared to determine if units are becoming more or less efficient with respect to other units and with respect to themselves over time. The use of DEA for successive periods would suggest whether the previously inefficient units have become relatively efficient through remedial actions taken and DEA would help locate other units that have become relatively inefficient.

Sensitivity Analysis

DEA suggests a variety of paths to reduce identified inefficiencies. Management may find that yet other paths are more feasible and/or less costly. DEA can be reapplied to the same set of units after adjusting the outputs and inputs to reflect management's plan to improve efficiency. DEA would indicate whether the changes anticipated will reduce the inefficiencies sufficiently for management purposes.

What are the Costs of Using DEA?

DEA can be run and interpreted with very modest amounts of training by individuals that have access to and are able to run any standard linear program package. Once the input and output data are available, the incremental cost of obtaining a DEA evaluation is minimal when such a linear program package is on hand.

The costs of identifying and collecting the output and input data not already available may be significant. While this cost might be incurred in conjunction with the DEA process, it is frequently considered valuable as an end in itself and is often an indicator of information gaps about aspects of operation which should be remedied regardless of the analytic techniques that will be used.

The area where significant costs are involved are in the followup to evaluate the way inefficiencies can be reduced and in identifying the techniques that exist in relatively efficient units that should be transferred to less efficient units. The value of DEA in this context is its ability to narrow management's focus to areas where inefficiencies are known to exist and where benefits of managerial action are likely to result in productivity improvements. Hence, these costs are likely to lead to benefits which compensate for costs of the DEA process.

In summary, the class of service organization which can be evaluated using DEA are those which produce multiple services with multiple inputs, where the efficient output/input relationships are not known or are difficult to identify, and where several units can be compared to evaluate relative performance. For this class of service units, DEA is a useful technique for locating ways to improve efficiency and profitability and can be a valuable complement to other management control tools and techniques used within these organizations. Considering the very few techniques available to evaluate and improve service business productivity, it would be reasonable for any manager of such an organization to consider the use of DEA to assist management in improving the productivity of its organization.

EXHIBIT 1

DEA is a linear programming technique that is structured as follows: Find the set of coefficients u's and v's that will give the highest possible efficiency ratio of outputs to inputs for the service unit being evaluated (E_e): i.e., the objective function is:

$$\text{(1a)} \quad \text{Maximize } E_e = \frac{u_1 0_{1e} + u_2 0_{2e} + \dots u_r 0_{re}}{v_1 I_{1e} + v_2 I_{2e} + \dots v_m I_{me}}$$

(Maximize the efficiency rating E for service unit e)

subject to the constraint that when the same set of u and v coefficients is applied to all other service units being compared, that no service unit will be more than 100% efficient as follows:

$$\text{Service Unit 1} \quad \frac{u_1 0_{11} + u_2 0_{21} + \dots u_r 0_{re}}{v_1 I_{11} + v_2 0_{21} + \dots v_m I_{m1}} \quad \leq 100\%$$

$$\text{Service Unit 2} \quad \frac{u_1 0_{12} + u_2 0_{22} + \dots + u_r 0_{r2}}{v_1 I_{1e} + v_2 0_{2e} + \dots + v_m I_{m2}} \quad \leq 100\%$$

$\vdots$

(1b)

$$\text{Service Unit e (as in (1a))} \quad \frac{u_1 0_{1e} + u_2 0_{2e} + \dots u_r 0_{re}}{v_1 I_{1e} + v_2 0_{2e} + \dots v_r 0_{re}} \quad \leq 100\%$$

$\vdots$

$$\text{Service Unit J} \quad \frac{u_1 0_{1j} + u_2 0_{2j} + \dots + u_r 0_{rj}}{v_1 I_{1j} + v_2 I_{2j} + \dots + v_m I_{mj}} \quad \leq 100\%$$

and such that the coefficient values are positive and non-zero.

$v_1, \dots v_r < 0$

(Ic)

$u_1, \dots u_m < 0.$

The data required to apply DEA is the actual observed outputs produced ($0_1 \dots 0_r$) and actual inputs used ($I_1 \dots I_m$) during one time period for each service unit in the set of units that are being evaluated. Hence, I_{mj} is the observed amount of the mth input used by the jth service unit, and 0_{rj} is the amount of rth output produced by the jth service unit.

If the value of E_e for the service unit being evaluated is less than 100%, then that unit is relatively inefficient and there is the potential for that unit to produce the same level of outputs with fewer inputs. (See [11], [4], [5], and [6] for further details on the theory and application of DEA).

Assume that the DEA evaluation would begin by evaluating the efficiency of bank branch B2. The problem would be structured as follows, based on the DEA model above and using the data in table 2:

Calculate the set of values for u_1, v_1, v_2 that will give B2 the highest possible efficiency rating,

$$\text{Maximize } E_{B2} = \frac{u_2(1000)}{v_1(30) + v_2(200)} \qquad \text{[This is the linear program } \underline{\text{objective function}}\text{]}$$

subject to the constraint that no service unit can be more than 100% efficient when the same values for u_1, v_1 and v_2 are applied to each unit:

$$\text{B1} \qquad \frac{u_1(1000)}{v_1(20) + v_2(300)} \leq 100\%$$

$$\text{B2} \qquad \frac{u_1(1000)}{v_1(30) + v_2(200)} \leq 100\%$$

$$\text{B3} \qquad \frac{u_1(1000)}{v_1(40) + v_2(100)} \leq 100\%$$

$$\text{B4} \qquad \frac{u_1(1000)}{v_1(20) + v_2(200)} \leq 100\%$$

$$\text{B5} \qquad \frac{u_1(1000)}{v_1(10) + v_{(400)}} \leq 100\%$$

and subject to the constraint that v_1, v_2 and u_1 are all greater than zero.

For B2, DEA calculates its efficiency rating to be 85.7% and the value for $u_1 = 1$, $v_1 = 1.436$ and $v_2 = 0.286$. DEA would be rerun for each branch in the objective function.

The results from running DEA fives times with each of the units in the ojective function is summarized in Table 2.

REFERENCES

1. Anthony, R. N., and J. S. Reece, Accounting, Text and Cases, sixth edition, Homewood, Illinois: Richard D. Irwin, Inc. 1979, Chapters 17 and 23.

2. Sasser, W. F., R. P. Olsen, and D. D. Wyckoff, Management of Service Operatings, Test, Cases and Readings, Boston, Massachusetts: Allyn and Bacon, Inc. 1978.

3. Anthony, R. N., and R. E. Herzlinger, Management Control in Nonprofit Organization, revised edition, Homewood, Illinois: Richard D. Irwin, Inc., 1980.

4. Charnes, A., W. W. Cooper and E. Rhodes, "Measuring the Efficiency of Decision Making Units," European Journal of Operations Research, Vol. 2, No. 6, November 1974, pp. 429-444.

5. Charnes, A., W. W. Cooper and E. Rhodes, "Short Communication: Measuring Efficiency of Decision Making Units," European Journal of Operations Research, Vol. 3, No. 4, July 1979, p. 339.

6. Charnes, A. W. W. Cooper, and E. Rhodes, "Evaluating Program and Magerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through," Management Science, Vol. 27, No. 6, June 1981, pp. 668-697/

7. Sherman, H. D., "A New Approach to Evaluate and Measure Hospital Efficiency," Sloan School of Management Working Paper #1427-83, February 1982.

8. Bessent, A., W. Bessent, J. Kennington, and B. Regan, "An Application of Mathematical Programming to Assess Productivity in the Houston Independent School District," Management Science, December 1982.

9. Lewin, A. Y., and R. C. Morey, "Evaluating Administrative Efficiency of Courts," Omega, (forthcoming).

10. Sherman, H. D. and F. Gold, "Evaluating Operating Efficiency of Service Businesses with Data Envelopment Analysis - Empirical Study of Bank Branch Operations," Sloan School of Management Working Paper #1444-83, June 1983.

11. Charnes, A., W. W. Cooper and H. D. Sherman, "A Comparative Study of Data Envelopment Analysis and Other Approaches to Efficiency Evaluation and Estimation," Center for Cybernetic Studies Research Report #451, University of Texas at Austin, November 1982.

Bar Code On
Last Page